Resource Equivalency Analysis for Western Snowy Plover
New Carissa Oil Spill, February 1999

May 24, 2005

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Summary

Four to eight Wester Snowy Plovers were killed by the New Carissa oil spill in February 1999. Resource equivalency analysis (REA) is used to evaluate the direct loss (birds killed) and indirect loss (lost reproduction) over time. Two compensation approaches are used: (A) identify in bird-years whether the emergency restoration conducted by the responsible party compensates the public for its losses; and (B) identify the number of acres needed to compensate the public based on the assumption that 30 acres produces 1 plover (Scenario 1, except in 2003) to 2 plovers (Scenario 2) annually. All figures are converted to 2004 values using a 3% discount rate to help facilitate decisionmaking based on a common, present value. The final results are summarized below and discussed in greater detail later in this report.

Final Results for Scaling Approach A

Debit (Loss from 4 to 8 Plovers)	Credit (Scenarios 1 & 2*)
6.48 to **12.96** direct bird-years lost	**51.73±40.57** bird-years restored (1) to **97.85±76.75** bird-years restored (2)
4.06±3.18 to **8.11±6.36** indirect bird-years lost	
10.54±3.18 to **21.08±6.36** total bird-years lost	

*Scenario 1 restores one plover per year in perpetuity (except 2003); Scenario 2 restores one plover per year through 2002, none in 2003, and then 2 plovers per year in perpetuity.

Final Results for Scaling Approach B

Debit (Bird-Years)		Relative Productivity (Scenarios 1 / 2*)	Credit Needed in Acres (High-Low Range of Acres)**			
			4 Plovers		8 Plovers	
4 Plovers	8 Plovers		Scenario 1	Scenario 2	Scenario 1	Scenario 2
6.48 direct	**12.96** direct	**1.72** (± 1.35) bird-years/acre (1) to **3.26** (± 2.56) bird-years/acre (2)	**3.76** direct (17.32 to 2.11)	**1.99** direct (9.24 to 1.11)	**7.52** direct (34.63 to 4.22)	**3.97** direct (18.47 to 2.23)
4.06 indirect (±3.18)	**8.11** indirect (±6.36)		**2.35** indirect (19.34 to 0.29)	**1.24** indirect (10.31 to 0.15)	**4.71** indirect (38.67 to 0.57)	**2.49** indirect (20.63 to 0.30)
10.54 total (±3.18)	**21.08** total (±6.36)		**6.11** total (36.65 to 2.39)	**3.23** total (19.55 to 1.26)	**12.22** total (73.31 to 4.79)	**6.46** total (39.10 to 2.53)

* Scenario 1 restores one plover per year in perpetuity (except 2003); Scenario 2 restores one plover per year through 2002, none in 2003, and then 2 plovers per year in perpetuity.
**Numbers are rounded by the computer; hand calculations may not sum to totals presented.

Introduction

A natural resource damage assessment determines whether a release or discharge has harmed any natural resources. If it did, the assessment determines what actions or funds, if any, are needed to "restore, replace, or acquire" the equivalent of the injured resources. There are two potential types of loss associated with an injury: (1) loss of baseline condition, which is the loss of resources as compared to their baseline condition (i.e., the condition they would be in now if the contamination was not present); and (2) the interim loss, which are the losses over time for which resources are in a depleted condition and less available to the public. Primary restoration projects (including acquisition) are used to bring resources to baseline condition. Compensatory restoration projects are used to offset the interim loss. When no primary restoration is pursued and natural recovery occurs, then the entire claim is for interim loss.

When the majority of damages are from birds like the threatened Western Snowy Plover, their value can be difficult to quantify in economic terms. Exactly how much are they worth to the public? An alternative approach to economic valuation is resource equivalency analysis (REA) (variation based on Unsworth and Bishop, 1994; Jones and Pease, 1997). An REA responds to the question, "What, but for the release, would have happened to the injured species?" In this case, what services would the four to eight plovers have provided over their expected lifespans (direct damages), including fledglings (indirect damages), if they had not been killed by the oil spill? With REA, the replacement services are quantified in physical units of measure such as *bird-years*.[1] The selected projects are scaled so that the quantity of replacement services equals the quantity of lost services in present value terms. In the end, responsible parties pay for (or implement) restoration projects that are sufficient to cover the public's interim losses. Because the services provided by compensatory restoration are qualitatively equivalent to the services lost due to the release, REA can avoid valuation altogether. When responsible parties are interested in cashing out, the projects may be costed out for a final settlement.

The remainder of this report is presented in three sections. The first section provides information on the injuries to Wester Snowy Plovers and the assumptions used in the REA. The second section provides an overview of the methodology used to calculate the interim loss to the public using REA. This section includes an analysis of direct lost services, indirect lost services, and characterization of the replacement services provided by the emergency restoration. An overview on how to scale projects and the final results are provided in the third section, along with comments on interpreting the results of the emergency restoration by the responsible party.

Injuries & Assumptions[2]

Direct Injury

Birds Injured: 4 to 8 Western Snowy Plovers

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[1] A *bird- year* refers to all services provided by one bird for one year. This measure of services is specific to to the type of bird since different birds provide different services.

[2] All research and data on the Western Snowy Plovers were provided by Larry Mangan, Bureau of Land Management, Coos Bay District, US Department of the Interior, Oregon.

Date of Injury: February 1999

Life History Data:

Table 1
Life History Data on Western Snowy Plover

Data	Western Snowy Plover
Average Age (years)	3
Average Life Expectancy (years)	5
Adult Survival Rate[3]	70.7%, exponential decline
Onset of Breeding	End of 1st Year
Percent of adult population which breeds	90% (50-50 female/male)
Birth Rates (# of fledglings per adult male)	1.04
Fledge 1-Year Survival Rate	51% ± 40%

Sources: Mark Stern, personal communication, 2004; Nur *et al.*, 1999.

Compensation

In this case, the goal is to identify how successful the emergency restoration activities are in compensating the public for the injury to plovers. Emergency restoration on 30 acres was partially funded by the responsible party. The results are:

1999 0 fledglings
2000 1 fledgling
2001 1 fledgling
2002 1 fledgling
2003 0 fledglings
2004 1 to 2 fledglings in perpetuity

Two approaches are considered in this analysis:

A. Lost bird-years are compared to restored bird years to identify the relative effectiveness of the emergency restoration effort in *discounted birds per year* (i.e., bird-years). This approach

[3]The expected adult annual survival ranges from 74.5% ± 13%. The assumption in this analysis is that adult survival between years is statistically the same after the first year. So for the 4 to 8 plovers, you would have had 100%/remaining years of life = x% adult survival per year. The root of annual survival by remaining years of life gives an exponentially declining survival rate over the remaining life span. Mathematically, this formula gives a 70.7% adult annual survival rate, which is consistent with the literature values.

assumes that it is not appropriate to evaluate plover restoration on a per acre basis. As a sensitive and threatened species, the plovers require at least an estimated 30 acres to generate one to two plovers per year.

B. Restoration efforts may be described in terms of relative productivity. One bird in one year produced by restoration on 30 acres means that 0.03 bird-years are produced per acre restored. Lost bird-years are scaled (divided by) bird-years per acre, to identify the number of *acres* which compensate the public.

The implications for the results is that Approach A reflects approximately 30 times higher numbers in bird-years (subject to rounding) than Approach B, which is in bird-years per acre. Both approaches have variation which results from the uncertainty in the survival rate of the fledglings for the first year.

Economic Assumptions

Discount Rate: 3%

Services provided in the future are discounted at an appropriate rate of discount to reflect the social rate of time preference, the rate at which society is willing to substitute between present and future consumption of natural resources. The real rate of interest and the government borrowing rate are recommended in the economics literature as the best measures of the social rate of time preference. Empirical evidence supports a 3% discount rate (e.g., Freeman, 1993; NOAA, 1999). Federal rulemakings also support a 3% discount rate for lost natural resource use valuation (61 FR 453; 61 FR 20584). The annual discount factor may be calculated as $(1+r)^{P-t}$, where r is the discount rate, P is the present time period, and t is the time period of lost services. In 2004, for example, the discount factor is 1.0, because any number raised to the zero power equals 1.0 ($1.03^{(2004-2004=0)} = 1.0$).

Analysis Using Resource Equivalency Analysis

Calculating Direct Losses

The first step in REA is to quantitatively identify lost bird-years from the oil spill. In this case, four to eight Western Snowy Plovers were killed by the oil spill in 1999 (Stern *et al.*, 2000). The average age is assumed to be three years and they are expected to live five years. Using the remaining lifespan and an exponentially declining rate of survival, 70.7% would have survived one more year, meaning that an average of 85% of the services would have been provided during the next year.[4] So, the equivalent of 3.4 to 6.8 birds were lost (85.4% x 4 = 3.414; 85.4% x 8 = 6.828). Of those that would have survived to age four, 70.7% should have survived to the end of the expected lifespan of five years. So, the equivalent of 2.4 to 4.8 birds were lost (85.4 x 70.7% x 4 = 2.414; 85.4% x 70.7% x 8 = 4.828). By multiplying the lost birds per year (bird-years) in current value by the corresponding discount factor (using a 3% discount rate and 2004 as the base year), the present value of lost bird-years results. In total, the value of lost

[4]At the time of the spill, there were 100% of the 4-8 plovers on site. Statistically, 70.7% would have been there one year later. Therefore, 85.4% would have been around mid-point after the spill (average services for age 3 to age 4).

services discounted to 2004 is **6.48 to 12.96 bird-years**. This figure may be viewed as the total *debit* created by the *direct injury* to the Western Snowy Plover.

Calculating Indirect Losses

In addition to the direct injury to the birds, one generation of lost fledglings is considered in a variation of an approach developed in the North Cape damage assessment case (Sperduto *et al.*, 1999). Based on 13 years of banding and observation data from the Oregon Coast (Mark Stern, personal communication, 2004) and a viability analysis for the Western Snowy Plover (Nur *et al.*, 1999) the following natural history data were used in this analysis:

- Statistically, approximately 70.7% of adults survive for one more year, averaging 85.4% during the year;
- 90% of the adult population that survives is expected to breed;
- 1.04 fledglings are produced per adult male, assumed to be 50% of the population;
- 51% ± 40% of the fledglings are expected to survive one year; and
- Each fledge that survives one year then has a 70.7% chance of surviving to the end of the second year and each year thereafter for a total of five years of life.

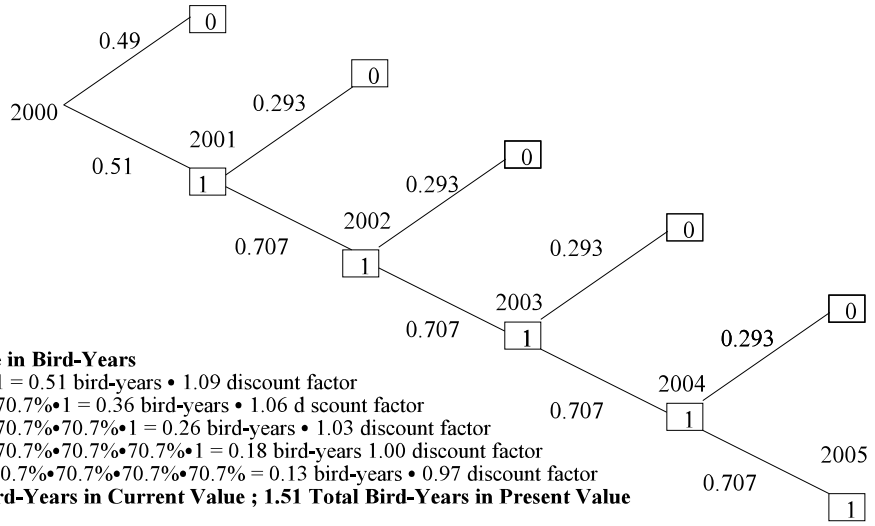
For 1999 to 2000, 85.4% of the four to eight plovers would have been alive for breeding season and 90% would have bred. Of the breeding birds, there would have been 1.04 fledglings per breeding male (assumed to be 50% of the population, so 1.54 to 3.08 breeding birds). For these fledglings, 51%±40% would have survived the first year, and 70.7% of those that survived the first year as fledglings would have survived as adults, and so on, for a lifespan of five years in total. The result is a loss of 2.48±1.94 to 4.96±3.89 bird-years for 1999 to 2000. Of the lost breeding birds, 70.7% of those in 2000 would have been around until 2001 to breed again, resulting in a loss of another 1.70±1.33 to 3.4±2.67 bird-years in present value. A total of **4.06 ±3.18 to 8.11±6.36 birds-years** may be viewed as the total *debit* created by the *indirect injury* to the plovers.

Calculating the Effectiveness of Emergency Restoration

Restored services are based on the expected number of fledglings and survival rates, as already described. The benefits are estimated to last in perpetuity, meaning that a new generation of birds may be expected to fledge each year, providing a flow of restored services.

Approach A. How many bird-years does the emergency restoration provide? One bird was restored in 2000 (see Figure 1). It has a 51% chance of surviving one year, and a 70.7% chance each year thereafter. Converting to present value, the expected value of one bird hatched in 2000 is 1.51 bird-years over five years. Another plover fledged in 2001, and another in 2002. In 2003, there were no fledglings. In 2004, 1 or 2 fledglings may result (Scenarios 1 and 2). The same methods are used to calculate the bird-years for its lifespan. Essentially, the bird-years decline by the 3% discount rate and are calculated in perpetuity (the point at which discounting drives the bird-years to near-zero). Under Scenario 1, if one fledge is produced annually in perpetuity (except for 2003), then **51.73±40.57 bird-years** are produced by the emergency restoration. Under Scenario 2, when one fledgling is produced each year from 2000 to 2002, none in 2003, and one to two fledglings are assumed to be produced from 2004 in perpetuity, then **97.85±76.75 bird-years** result.

Figure 1
Expected Value of Having One Western Snowy Plover Survive Through Its Five-Year Lifespan
(Fledged in 2000; Dies in 2005)



Expected Value in Bird-Years
2000: 51% • 1 = 0.51 bird-years • 1.09 discount factor
+ 2001: 51% • 70.7%•1 = 0.36 bird-years • 1.06 d scount factor
+ 2002: 51% • 70.7%•70.7%•1 = 0.26 bird-years • 1.03 discount factor
+ 2003: 51% • 70.7%•70.7%•70.7%•1 = 0.18 bird-years 1.00 discount factor
+ 2004: 51% •70.7%•70.7%•70.7%•70.7% = 0.13 bird-years • 0.97 discount factor
= **1.43 Total Bird-Years in Current Value ; 1.51 Total Bird-Years in Present Value**

Approach B. How many acres of restoration compensate the public for injury to plovers? Typically, the second step in REA is to quantitatively characterize the replacement services provided by compensatory restoration. At each point in time, replacement services are described as a proportional equivalent of baseline called *relative productivity*. Relative productivity describes the net ecological services provided by a compensatory restoration option relative to the baseline productivity of the injured habitat. In this analysis, emergency restoration on 30 acres produces one bird per year (or 0.03 bird-years per acre) in perpetuity (except for 2003) under Scenario 1. In present value, **1.72±1.35 bird-years** are produced per acre restored. In Scenario 2, the restoration produces one bird per year from 2000 to 2002, none in 2003, and two birds per year (2 birds ÷ 30 acres = 0.07 bird-years per acre) from 2004 in perpetuity. In this case, **3.26±2.56 bird-years** in present value are produced per acre restored.

Scaling & Results

Approach A. The effectiveness of the emergency restoration is evaluated by comparing the number of bird-years restored relative to the number bird-years lost from the New Carissa oil spill. The results for this approach are provided in Table 2.

Approach B. The third step in REA is usually to identify the project scale that will equate the total discounted quantity of replacement services to the total discounted quantity of lost services. The project scale for this approach is calculated by dividing the total discounted value of lost services in bird-years by the total discounted value of relative productivity for the emergency restoration. This calculation ensures that the selected compensatory restoration project will provide a *credit* just equal to the *debit*. Table 3 provides a summary of how many acres would compensate for the injured plovers.

Table 2
Final Results for Scaling Approach A

Debit (Loss from 4 to 8 Plovers)	Credit (Scenarios 1 & 2*)
6.48 to **12.96** direct bird-years lost	**51.73±40.57** bird-years restored (1) to **97.85±76.75** bird-years restored (2)
4.06±3.18 to **8.11±6.36** indirect bird-years lost	
10.54±3.18 to **21.08±6.36** total bird-years lost	

*Scenario 1 restores one plover per year in perpetuity (except 2003); Scenario 2 restores one plover per year through 2002, none in 2003, and then 2 plovers per year in perpetuity.

Table 3
Final Results for Scaling Approach B

Debit (Bird-Years)		Relative Productivity (Scenarios 1 / 2*)	Credit Needed in Acres (High-Low Range of Acres)**			
			4 Plovers		8 Plovers	
4 Plovers	8 Plovers		Scenario 1	Scenario 2	Scenario 1	Scenario 2
6.48 direct	**12.96** direct	**1.72** (± 1.35) bird-years/acre (1) to **3.26** (± 2.56) bird-years/acre (2)	**3.76** direct (17.32 to 2.11)	**1.99** direct (9.24 to 1.11)	**7.52** direct (34.63 to 4.22)	**3.97** direct (18.47 to 2.23)
4.06 indirect (±3.18)	**8.11** indirect (±6.36)		**2.35** indirect (19.34 to 0.29)	**1.24** indirect (10.31 to 0.15)	**4.71** indirect (38.67 to 0.57)	**2.49** indirect (20.63 to 0.30)
10.54 total (±3.18)	**21.08** total (±6.36)		**6.11** total (36.65 to 2.39)	**3.23** total (19.55 to 1.26)	**12.22** total (73.31 to 4.79)	**6.46** total (39.10 to 2.53)

* Scenario 1 restores one plover per year in perpetuity (except 2003); Scenario 2 restores one plover per year through 2002, none in 2003, and then 2 plovers per year in perpetuity.
**Numbers are rounded by the computer; hand calculations may not sum to totals presented.

Comments on Interpreting Results

Approach A. A worst-case scenario would be that eight plovers were killed and fledglings would have had the highest survival rate under their pre-spill natural conditions, resulting in a maximum loss of 27.436 (approximately 12.96+8.11+6.36) bird-years. Similarly, a worst-case scenario for emergency restoration is that it could only produce one fledgling per year in perpetuity (Scenario 1, except in 2003), and the fledglings have a minimum survival rate (51%-40%=11%). Under these worst-case conditions, only 11.16 (51.73-40.57) bird-years would be restored, implying that restoration is off by a factor of almost two and one-half. Scenario 2 with a minimum survival rate also falls slightly short (97.85-76.75)

at 21.10 bird-years restored bird-years). The other scenarios show that emergency restoration equals or exceeds the number of bird-years which require compensation under natural resource damage assessment.

Approach B. The worst-case scenario for this approach again assumes that eight plovers were killed and fledglings would have had the highest survival rate under their pre-spill natural conditions, resulting in a maximum loss of 27.436 bird-years (12.96+8.11+6.36). Assuming that emergency restoration only produces one fledgling per year in perpetuity (Scenario 1, except in 2003), and those fledglings have a minimum survival rate, approximately 73.31 acres [27.436÷(1.72-1.35)] of restored plover habitat are needed for compensation. The original emergency restoration would be short about 43.3 acres. The worst-case scenario of acreage needed for 8 plovers under restoration Scenario 2 falls short by around 9 acres [(12.96+ 8.11 +6.36)÷(3.26-2.56) = 39.097 acres]. The worst-case scenario for four plovers for Scenario 1 is short about 6.65 acres [(6.48+4.06+3.18)÷(1.72-1.35) = 36.65 acres]. The other scenarios indicate that emergency restoration more than compensates for the original injury.

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